CHAPTER 6

BITUMINOUS MATERIALS COURSES

6-1. General. Bituminous surfaces provide a resilient, waterproof, load distributing medium that protects the base course against the detrimental effects of water and the abrasive action of traffic. The flexibility of bituminous pavement permits slight adjustments in the pavement structure, owing to consolidation, without detrimental effect. However, bituminous concrete is unsatisfactory for use where heat and blast effects from jet aircraft are severe. Also, asphaltic concrete is not resistant to fuel spillage and is satisfactory only where spillage is slight and very infrequent.

a. Bituminous mixes. The following part of this chapter provides an abbreviated guide to the design of hot mix bituminous surface and base courses. For a complete treatment on the criteria requirements, selection of materials, testing, design, and plant control of hot mixes, tar-rubber mixes, and surface treatments, refer to appendix A.

b. Definitions. See table 6-1 for terminology used in flexible pavement design.

6-2. Selection of materials.

a. Bituminous materials. Bituminous materials include asphalts, tars, and tar-rubber blends.

(1) Asphalts. Asphalt products are the normal choice for use in bituminous mixes for reasons of availability, serviceability, and economy.

(2) Tars. Tars are more susceptible to temperature changes than similar grades of asphalt; tars are also more toxic and difficult to handle. However, tars are more resistant to jet fuel spillage and are less likely than asphalts to strip from hydrophilic aggregates in the presence of water.

(3) Tar rubber blends. Mixtures of tar and synthetic rubber have increased resistance to fuel spillage and temperature changes. Consider use of tar-rubber blends for pavements where jet fuel spillage is infrequent.

b. Aggregates.

(1) Suitability of rock types. Alkaline rocks (limestone, dolomite) provide better adhesion with asphaltic films in the presence of water than acid or silicious rocks (granite, quartzite). Where acid rocks are used, addition of an antistripping agent or hydrated lime may be required.

Table 6-1. Specialized Terminology for Bituminous Pavement

Item	Description
Coarse aggregate	Material larger than the No. 4 sieve
Fine aggregate	Material passing the No. 4 sieve and retained on No. 200 sieve
Mineral filler	Material finer than the No. 200 sieve
Wearing course	The top layer of bituminous concrete surface
Binder or intermediate course	The leveling or transition layer of bituminous concrete placed directly on a base course
Prime coat	A surface treatment of liquid bitumen applied to a nonbituminous base course before bituminous pavement is placed. Purpose is to penetrate and seal surface of base course
Tack coat	Bituminous emulsion or liquid bitumen placed on an existing concrete or bituminous pavement to provide good bond with the new bituminous course
Marshall stability value	The load in pounds causing failure in a compacted specimen of hot-mix bituminous concrete when tested in the Marshall apparatus
Flow	Total deformation in hundredths of of an inch at point of maximum load in the Marshall Stability Test
Percent air voids	That part of the compacted bitumen-aggregate mixture not occupied by aggregate or bitumen expressed in percent of total volume
Percent voids filled with bitumen	Percentage of voids in a compacted aggregate mass that are filled with bituminous cement
Penetration	The relative hardness or consistency of an asphalt cement. Measured by the depth a standard needle will penetrate vertically into a sample of asphalt under known conditions of temperature, loading, and time
Viscosity	A measure of the ability of a bitumen to flow at a given temperature range. The stiffer the bitumen the higher the viscosity
Percent voids in the mineral aggregate (VMA)	The volume of void space in a compacted paving mix that includes the air voids and effective asphalt content, expressed as a percent of the volume of the sample

(2) Crushed aggregate. The coarse and fine aggregates used for airfield pavement surface should be crushed materials, in order to assure high stability and performance. Bituminous base courses, however, may include natural materials in the fine fraction.

(3) Maximum size. In general, the maximum size of aggregate for the wearing course should not exceed 3/4 inch; in no case should the aggregate size exceed one-half the thickness of the compacted wearing course or two-thirds the thickness of any binder or intermediate course.

(4) Mineral filler. The type and quantity of mineral filler used affects the stability of the mix. For surface course mixes, mineral filler should be limestone dust, portland cement, or other inert similar materials. For bituminous bases natural filler is frequently adequate.

6-3. Design of bituminous concrete mix.

a. Criteria. Use the procedures and criteria described in appendix A and as condensed below for the design of hot mix bituminous concrete. Approved design mixes are available from Army, Federal, and state agencies which would meet the requirements outlined in this manual for mobilization construction. Existing acceptable design mixes should be utilized whenever possible. Where tests for aggregate and bituminous mix are required see table 6-2.

b. Asphalt cement grades. At present, in the United States, asphalt cement is specified by one of the following:

- Penetration grades

- AC viscosity grades

- AR viscosity grades

Correlation between penetration grades and viscosity grades for asphalts from different producers is not possible. Figure 6-1 gives the recommended grades for each area of the United States by penetration and viscosity designation. These recommendations should be tempered by local practice. Use the penetration grade designation in the areas when penetration grade asphalt is produced. The penetrations of AC and AR grades do not necessarily fall within the range of recommended values. In areas where viscosity grades are produced, determine the sources with acceptable penetration and approve those grades. See table 6-3 for specifications for asphalt, tars, and tar-rubber blends.

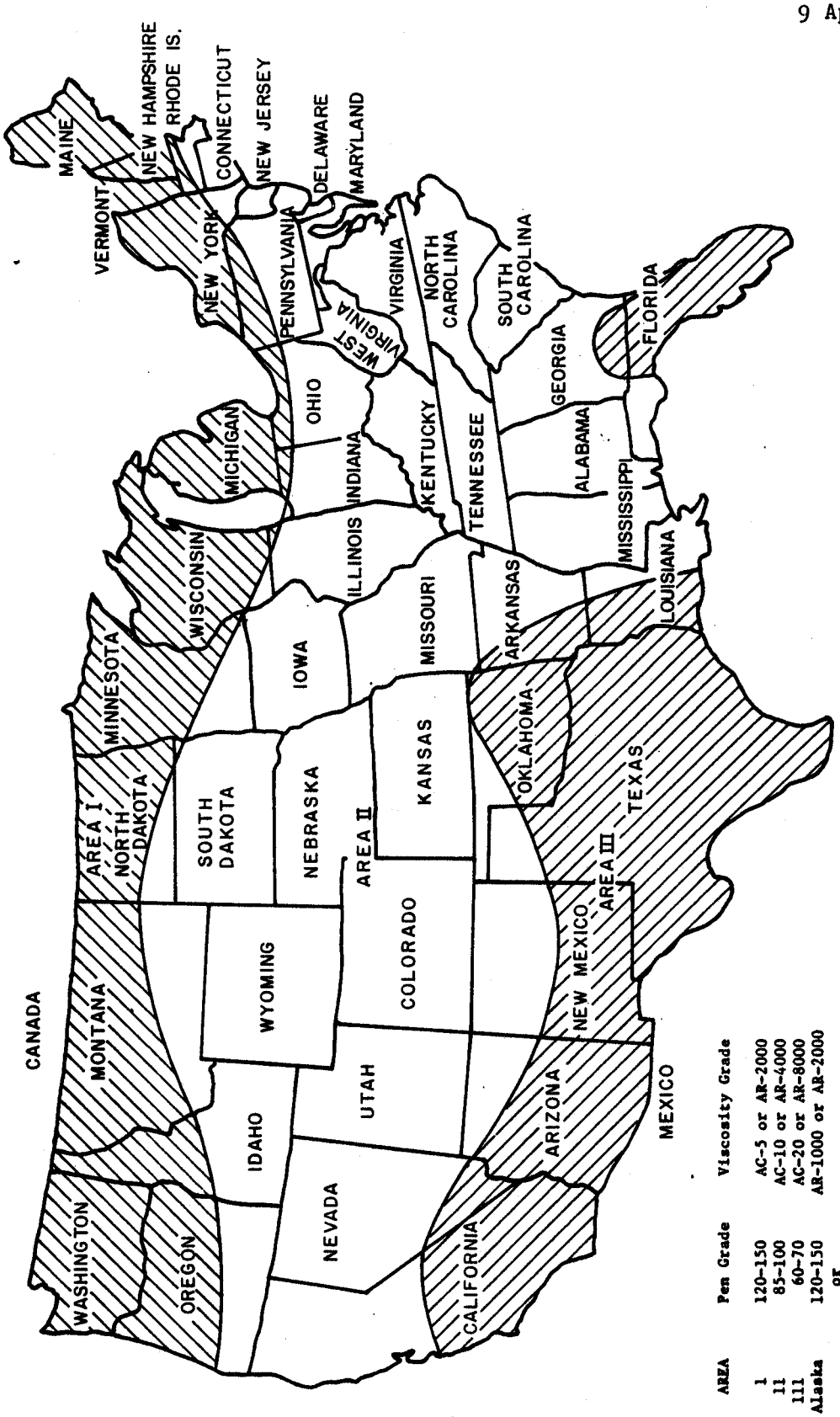
Table 6-2. Tests for Aggregate and Bitumen Mix

Test	Test Standard[1]	Comments
Sampling aggregates	ASTM D 75	
Mineral filler	ASTM D 242	Specification for mineral filler
Resistance to abrasion-coarse aggregate	ASTM C 131	Not more than 40 percent for surface courses. Not more than 50 percent for base courses.
Soundness-course aggregate	ASTM C 88	After five cycles loss should not be more than: 12 percent sodium sulfate test or 18 percent magnesium sulfate test
Absorption and apparent specific gravity-course and fine aggregate	ASTM C 127 ASTM C 128	Use apparent specific gravity for mix design when absorption is 2.5 percent or less
Marshall method for design of bituminous mixes	MIL-STD 620 Method 100 ASTM D 1559	See text for requirements
Unit weight of aggregate	ASTM C 29	Graded crushed slag as used in mix should have a compact weight of not less than 70 pcf
Immersion compression test-bitumen mix	MIL-STD 620 Method 104	Require an index of 75 or better for acceptance[2]

[1]Testing for Army airfields will be by MIL-STD where shown.

[2]Where index is less than 75, potential stripping is indicated. Add a recognized commercial anti-stripping agent or 1/2 to 1 percent hydrated lime and retest, or replace aggregate with new aggregate which will conform to requirements of immersion-compression test.

U. S. Army Corps of Engineers



AREA	Pen Grade	Viscosity Grade
I	120-150	AC-5 or AR-2000
II	85-100	AC-10 or AR-4000
III	60-70	AC-20 or AR-8000
Alaska	120-150 or 150-200	AR-1000 or AR-2000
Hawaii	60-70	AR-8000

NOTE: The penetration of viscosity graded asphalts do not necessarily fall within the ranges indicated. Where specific penetration requirements are desired, they should be so stipulated.

U. S. Army Corps of Engineers

FIGURE 6-1. SELECTION GUIDE FOR ASPHALT CEMENT

Table 6-3. Specifications for Bituminous Materials

Bitumen	Specification
Asphalt cement (penetration grades)	ASTM D 946
Asphalt cement (AC and AR grades)	ASTM D 3381
Asphalt, liquid (slow-curing)	ASTM D 2026
Asphalt, liquid (medium-curing)	ASTM D 2027
Asphalt, liquid (rapid-curing)	ASTM D 2028
Asphalt, emulsified	ASTM D 977
Asphalt, cationic emulsified	ASTM D 2397
Tar	ASTM D 490
Tar cement (base for rubberized tar)	ASTM D 2993
Rubberized tar cement	ASTM D 2993

c. Selection of materials for mix design. Use materials (bitumen, aggregates, mineral filler) in the mix design that meet the requirements of the specifications and that will be used in the field for construction. Aggregate gradations are shown in table 6-4.

6-4. Testing for mix design.

a. General. Testing will indicate the properties that each blend selected will have after being subjected to appreciable traffic. A final selection of aggregate blend and filler will be based on these data with due consideration to the relative costs of the various mixes.

b. Test procedures. Design bituminous paving mixes by the Marshall method. Compaction requirements are summarized as follows:

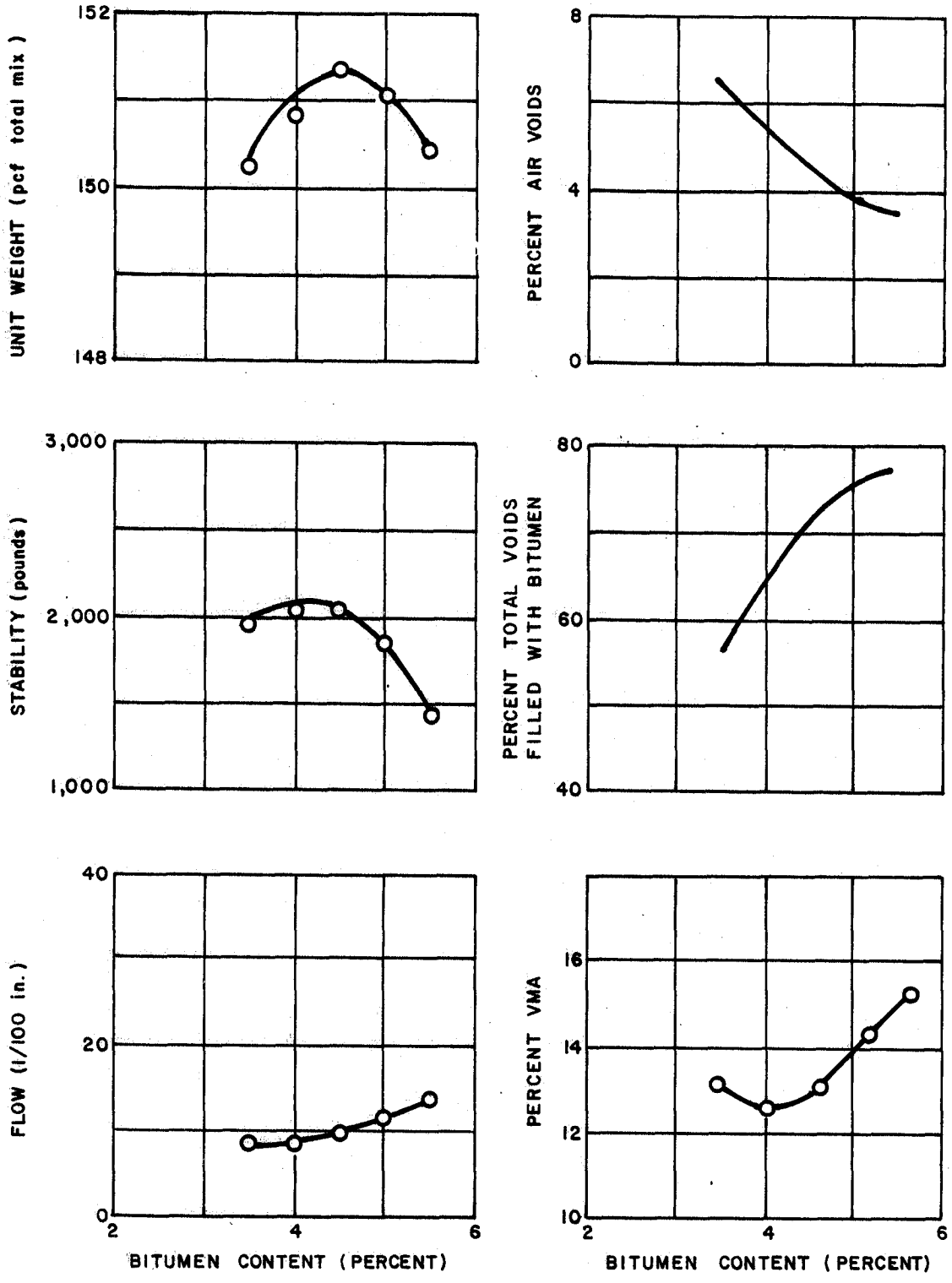
Types of Traffic	Design Compaction Requirements
Tire pressure 100 psi and over	75 blows Marshall method
Tire pressure less than 100 psi	50 blows Marshall method

c. Optimum bitumen content and adequacy of mix. Plot data obtained in graphical form as shown in figure 6-2. See table 6-5 for point-on-curve and adequacy of mix criteria. The conventional Marshall method approach is as follows:

Table 6-4. Aggregate Gradations for Bituminous Concrete Pavements

Sieve Size	Percent Passing by Weight											
	1-1/2-in. Maximum[1]		1-in. Maximum		3/4-in. Maximum		1/2-in. Maximum		3/8-in. Maximum		No. 4 Maximum	
	Low Pressure[2]	High Pressure[3]	Low Pressure	High Pressure	Low Pressure	High Pressure	Low Pressure	High Pressure	Low Pressure	High Pressure	Low Pressure	Pr
Wearing Course												
1-1/2 inch	100	--	--	--	--	--	--	--	--	--	--	
1 inch	87±8	--	100	100	--	--	--	--	--	--	--	
3/4 inch	79±9	--	90±7	90±6	100	100	--	--	--	--	--	
1/2 inch	70±9	--	81±9	81±7	89±9	89±7	100	100	--	--	--	
3/8 inch	63±9	--	75±9	75±7	82±9	82±7	86±9	86±7	100	--	--	
No. 4	51±9	--	60±9	60±7	66±9	66±7	66±9	66±7	85±10	--	100±	
No. 8	42±9	--	47±9	47±7	53±9	53±7	53±9	53±7	72±10	--	86±12	
No. 16	34±9	--	37±9	37±7	41±9	41±7	41±9	41±7	56±12	--	72±16	
No. 30	26±9	--	27±9	27±7	31±9	31±7	31±9	31±7	42±10	--	57±12	
No. 50	19±8	--	19±8	19±6	21±8	21±6	21±8	21±6	29±9	--	43±17	
No. 100	12±6	--	12±6	13±5	13±6	13±5	13±6	13±5	18±7	--	28±12	
No. 200	4±3	--	4±3	4.5±1.5	4±3	4.5±1.5	4±3	4.5±1.5	8±3	--	9±5	
Binder or Intermediate Course												
1-1/2 inch	100	--	--	--	--	--	--	--	--	--	--	
1 inch	84±9	--	100	100	--	--	--	--	--	--	--	
3/4 inch	76±9	--	83±9	90±6	100	100	--	--	--	--	--	
1/2 inch	66±9	--	73±9	81±7	82±9	89±7	100	100	--	--	--	
3/8 inch	59±9	--	64±9	75±7	72±9	82±7	83±9	86±7	--	--	--	
No. 4	45±9	--	48±9	60±7	54±9	66±7	62±9	66±7	--	--	--	
No. 8	35±9	--	37±9	47±7	41±9	53±7	47±9	53±7	--	--	--	
No. 16	27±9	--	28±9	37±7	32±9	41±7	36±9	41±7	--	--	--	
No. 30	20±9	--	21±9	27±7	24±9	31±7	28±9	31±7	--	--	--	
No. 50	14±7	--	16±7	19±6	17±7	21±6	20±7	21±6	--	--	--	
No. 100	9±5	--	11±5	13±5	12±5	13±5	14±5	13±5	--	--	--	
No. 200	5±2	--	5±2	4.5±1.5	5±2	4.5±1.5	5±2	4.5±1.5	--	--	--	

[1] 1-1/2 inch maximum surface course gradation will be used only for thick-lift pavements (3-inch or more).
[2] Use low-pressure gradation for pavements subjected to aircraft with tire pressures less than 100 psi.
[3] Use high-pressure gradation for pavements subjected to aircraft with tire pressures of 100 psi or greater.



U. S. Army Corps of Engineers

FIGURE 6-2. ASPHALT PAVING MIX DESIGN, TYPICAL MIX

(1) Determine the optimum bitumen content by averaging the following values:

Bitumen content at peak of stability curve

Bitumen content at peak of unit weight curve (for wearing course only)

Bitumen content at the appropriate point of air voids curve

Bitumen content at the appropriate point on voids filled with bitumen curve

(2) Check for adequacy of mix for stability, flow, air voids, and voids filled with asphalt.

Table 6-5. Procedure for Determining Optimum Bitumen Content and Adequacy of Mix for Use With Aggregate Showing Water Absorption of 2-1/2 Percent or Less

	Wearing Course		Intermediate and Base Course	
Test Property	Point on Curve for Optimum Bitumen Content	Adequacy of Mix Criteria	Point on Curve for Optimum Bitumen Content	Adequacy of Mix Criteria
Marshall Stability 75 blows	peak of curve	1,800 or higher	peak of curve	1,800 or higher
Unit weight	peak of curve	not used	not used	not used
Flow	not used	16 or less	not used	16 or less
Percent air voids	4	3-5	6	5-7
Percent voids filled with bitumen	75	70-80	60	50-70

d. Typical example. The determination of bitumen content and adequacy of mix is illustrated by the following example using the curves in figure 6-2 and criteria in table 6-5. The example is for a wearing course mix with 3/4-inch maximum aggregate.

(1) Determination of optimum bitumen content

Point on Curve	Bitumen Content
Peak of stability curve	4.3 percent
Peak of unit-weight curve	4.5 percent
At 4 percent air voids curve	4.8 percent
At 75 percent voids filled with asphalt curve	4.9 percent
Average	4.6 percent

The optimum bitumen content of the mix in this example is 4.6 percent based on the weight of total mix.

(2) Check for adequacy of mix.

Test Property	At Optimum or 4.6 Percent Bitumen	Criteria for Adequacy
Flow	11	Less than 16
Stability	2,050	More than 1,800
Percent air voids	4.3	3 to 5 percent
Percent voids filled with bitumen	72	70 to 80 percent

The paving mix would be considered satisfactory for airfield traffic since it meets the criteria for adequacy.

6-5. Thickness of bituminous courses.

a. Intermediate and wearing course. Bituminous courses will be placed and compacted in such thicknesses to achieve density and smoothness requirements. The thickness of the wearing course should not exceed 2 inches compacted thickness and each intermediate course layer should not exceed 4 inches. The wearing course mix may be used for both courses.

b. Bituminous base course. The maximum lift of a bituminous base course should not exceed 6 inches.

6-6. Bituminous spray coats.

a. Prime coats. Prime coats should be applied to accomplish the following:

(1) To seal surface of base course in areas where rain may be expected prior to placement of the asphalt surface.

(2) To bind together "dusty" base surfaces.

(3) To bind together a base surface for protection against construction traffic.

(4) To bind overlying bituminous courses to the base.

Preferred materials for use as prime coats are the liquid asphalts MC-70, MC-250, RC-70, RC-250, and the tars RT-2 and RT-3. Application rates of the liquid asphalts and tars are between 0.15 and 0.4 gallon per square yard. Sufficient bitumen should be used to seal the voids but not more than can be readily absorbed. Asphalt emulsions have been used experimentally with varying success for prime coats. Emulsions do not penetrate as do liquid asphalts and may require a sand seal to prevent tracking. Emulsions used for priming are SS-1 and SS-1h diluted with 50 percent water and applied at approximately 0.1 gallon per square yard.

b. Tack coats. Tack coats are required on existing pavements to insure a bond with the new overlying bituminous concrete course. Tack coats may not be required between new layers of pavement where the upper layer is immediately constructed as the lower layer is completed. However, tack coats should be used on layers where construction is halted and placement of the overlaying layer is delayed. Tack coats should also be installed on surfaces which have become coated with fine sand or dust and on surfaces soiled from construction traffic. Soiled surfaces must be cleaned before application of a tack coat.

(1) Materials. Use emulsified asphalt SS-1, SS-1h, CSS-1, or CSS-1h diluted with equal parts of water. The following liquid asphalts or tars may also be used, RC-70, RT-6, and RT-7.

(2) Application. Apply tack coats with a pressure distributor at the rate of 0.05 to 0.15 gallon per square yard.